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COMPOSITION AND PRODUCTIVE ENERGY OF POULTRY FEEDS AND RATIONS

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The productive energy values of a number of poultry feeds have been measured by means of the gains of protein and fat in growing chickens. The productive energy of poultry feeds can be calculated by means of the energy production coefficients given in this publication. The calculated productive energy value and the digestible protein are given for a number of poultry feeds of average composition. The productive energy was calculated for a number of rations recommended by various experts. The average productive energy, in therms per 100 pounds, was 81.6 for all-mash chicken starter, 87.9 for all-mash growing diet and 91.7 for mash and grain; 83.1 for all-mash laying diet and 89.5 for mash with grain; 81.4 for all-mash breeding diet and 86.5 for mash with grain. Feeding experiments with growing fowls should include the quality of the animals produced, especially the fat content, as well as the gains in weight. Fowls making the same gains in weight are not necessarily of the same degree of fatness.

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COMPOSITION AND PRODUCTIVE ENERGY OF POULTRY FEEDS AND RATIONS

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Little attention has usually been given the total digestible constituents or energy contents of feeds and rations when used in feeding chickens. As explained by Titus (25) in discussing the nutritive requirements of the several classes of chickens, particular attention is given to the problem of supplying protein, minerals, and vitamins in quantities that will sustain a rapid rate of growth or of egg production. No attempt is made to control the carbohydrate intake and only in the case of chickens being finished for market is the fat intake given any special consideration.

One reason for this omission has been the deficiency of adequate data as to the energy values of chicken feeds. Such data is presented in this publication, and should be useful in comparing the energy values of different feeds, formulating rations and studying the nutritive requirements of chickens. Recommendations of mixtures for chicken feeds are usually based upon experimental work with such mixtures; this is the correct procedure and scientific theories should always be put to the test of practical experiment. The application of the Texas work on productive energy to poultry nutrition and feeding will be discussed in subsequent pages.

For a number of years, a comprehensive investigation has been carried on by the Division of Chemistry of the Texas Agricultural Experiment Station to ascertain the energy values of foods and feeds as measured by the production of fat and flesh on growing chickens and rats. Previous publications have discussed the digestibility of some chicken feeds (6), the utilization of the energy of feeds by growing chickens (15), the energy values of corn bran, rice bran, and rye flour (14), the relation of gain in weight to gain in energy content of growing chickens (10), the metabolizable energy of chicken feeds (16), the productive energy of alfalfa meal and some other chicken feeds (17), the productive energy values of a number of feeds as measured by chickens (18), productive energy of certain feeds as measured by production of fat and flesh by growing rats (9), and the maintenance requirements of chickens and productive energy of feeds as related to age (12).

The object of the work was to measure the energy values of feeds in terms of the use made of it by chickens. The work here presented includes methods of calculating the productive energy and digestible protein for chickens from the chemical analysis by the use of production coefficients;

it gives average productive values and digestible protein values for a number of chicken feeds and rations and discusses the application of the use of the productive energy values in the feeding of chickens.

Determination of the Productive Energy of Poultry Feeds

Productive energy was calculated from the gains in protein and fat made by growing chickens. The first step was to ascertain the productive energy of a standard ration (15). Day-old chickens were fed the ration decided upon for a period of about a week. The chickens were then weighed and divided into 4 groups, three groups being practically equal in total weight. One group was killed for analysis. Another group was placed upon full feed, and a third group was placed upon limited feed, the quantity fed being about half that eaten by those on full feed, and the amount fed daily being based upon the quantity eaten by the group which was full fed. The fourth group was used to ascertain the digestibility of the ration being fed. The chickens were fed individually in battery brooders. At the end of the desired period of time, the chickens were killed and the protein and fat in them was determined. The grams of protein was multiplied by 5.66 and the grams of ether extract was multiplied by 9.35 to secure the calories of energy contained in the chickens. The analysis of the chickens at the beginning of the experiment were used to ascertain the composition of the experimental chickens at the beginning of the feeding. The energy content at the end less that at the beginning gave the gains of the chickens. Full details of the procedure have already been published (15). The productive energy of the feed eaten by the chickens was used partly for maintenance and partly for gain. The data were used to ascertain both the productive energy of the ration, and the productive energy used for maintenance. The two lots of chickens were fed different quantities of the same ration, at the same time and under the same conditions. Calculations were made on the assumption that the maintenance requirements vary either according to the average weight, or according to the average surface area. Algebraic equations were set up and solved to ascertain the value of the ration for productive energy and for maintenance.

The equations used were, for the chickens on limited feed (1), $WM+G=FX$; and for the chickens on full feed, (2) $VM+H=DX$. Expressed in words, the average weight of the chickens, in grams (W or V) multiplied by the maintenance requirements for the period of the experiment in calories of productive energy per gram (M), plus the gain in protein and fat expressed in calories (G or H) is equal to the quantity of the feed eaten in grams (F or D), multiplied by the productive energy in calories per gram (X). After inserting the data for each experiment, the equations were solved for the value of productive energy (X), and for maintenance (M).

The productive energy value of the ration as an average of 6 experiments for 21 days and 4 experiments for 42 days was found to be 1.79 calories per gram of total ration and 2.78 calories per gram of effective digestible nutrients (15). The values secured in the individual experiments ranged from 1.75 to 1.83 calories per gram of total ration and from 2.60 to 3.04 calories per gram of effective digestible nutrients. The values secured with the average live weights were more nearly in accord with results published by other workers than the values secured with the surface area basis.

After the productive energy values of the ration had been ascertained, it was necessary next to ascertain the productive energy of the individual feeds used in the ration; especially for corn meal and for casein, to be used as standards. For this purpose (17) 4 groups of chickens, usually of 6 each, were fed individually at the same time, one on a standard ration containing corn meal, and the others on similar rations, in which part of the corn meal or corn meal and casein were replaced by the feed to be tested, to the extent of 50 percent if practical; otherwise with as high a percentage as was practical if 50 percent was excessive. By comparing the gains of energy in protein and fat made by the chickens on the ration containing the feed to be tested, with the gains made by the chickens fed the corn meal ration, and with due allowance for differences in live weights, the productive energy values of the different feeds in the standard ration, compared with that of corn meal, were ascertained. Then, using the relative productive energy values of the feeds other than corn meal, the productive energy of corn meal was calculated (17). In a series of other experiments, (12, 18) the productive energy values of a number of other feeds were ascertained.

Observations on the Productive Energy Values of Poultry Feeds

There are wide differences in the productive energy values of different chicken feeds as ascertained by the experimental work. Typical average values are, in calories per 100 grams, 43 for alfalfa leaf meal, 204 for whole barley, 129 for dried buttermilk, 114 for corn gluten feed, 120 for cottonseed meal, 121 for meat and bone scraps, 114 for dried skim milk, 13 for oat hulls, and 206 for whole wheat, compared with 241 for corn meal, used as a standard.

Differences in the productive energy values of the different feeds were found to be due chiefly to the differences in their content of digestible nutrients. When the productive energy values were calculated for 100 grams of the effective digestible nutrients instead of for 100 grams of the feed, the energy values of the effective digestible nutrients of most of the feeds were within 10 percent of that of corn meal.

About 72 percent of the metabolizable energy of corn meal was productive energy and could be stored as protein or fat. That is to say, the loss of utilization of metabolizable energy for production of protein and fat from corn meal was approximately 28 percent.

Within the same experiments, there were variations in the energy content and the live weight between individual chickens (Table 8, Bul. 571)

(15), and in the protein and fat content of the individual chickens (Table 9, Bul. 571) (15), as shown by the standard deviations. For the purpose of calculations, when the productive energy was assumed to be constant and the maintenance requirements calculated, there were appreciable differences in the productive energy used for maintenance by individual chickens in the same experiment (Tables 15, 16, Bul. 571) (15). When the maintenance requirements were assumed to be constant and the productive energy calculated, there were differences in the productive energy of the feeds as utilized by individual chickens (Tables 18, 19, Bul. 571) (15), the average of the standard deviations being about 10 percent of the total productive energy of the ration. Variations in the productive energy of the same ration were probably due chiefly to differences in energy used for maintenance, especially movements of the body. Some chickens are more active than others.

There are wide differences in the productive energy used for maintenance by chickens fed at different times on approximately the same ration (12). On a ration averaging 16.2 percent protein, the maintenance requirements in calories of productive energy per day per 100 grams ranged from 12.4 to 20.5 with an average of 15.8 and a standard deviation of 1.7 in 19 tests (12). On a ration containing 18.1 to 21 percent protein and averaging 19.5, the maintenance requirements ranged from 9.4 to 17.7 calories per 100 grams of live weight, with an average of 13.6 and a standard deviation of 2.5 calories.

The data indicated that chickens fed on rations low in protein had higher maintenance requirements than those fed on rations containing high percentages of protein. Chickens on rations averaging 17 percent of protein had high average maintenance requirements of 15.8 calories of productive energy per day and 100 grams of live weight, while those on rations containing 21 to 24 percent protein averaged 12.6 calories per day per 100 grams live weight.

For the purpose of calculating the productive energy of the feeds which replaced corn meal in any given experiment, it is necessary to assume that the maintenance requirements for the experimental ration average the same per period per 100 grams as for the standard corn meal ration fed in the same experiment. This assumption is not always correct (12); therefore, the differences between the productive energy values found in different experiments are due in part to differences in maintenance requirements between the two groups compared. Hence repetitions of the work several times are necessary to ascertain the correct value. The experimental work has established definitely that the productive energy of the same feed is more nearly constant than the maintenance requirements of the chickens.

Substitution of the feed to be compared with corn meal in quantities as high as possible has necessarily given rise to some rations widely different from those used in commercial feeding of chickens. These substitutions have resulted in some rations with wide differences in protein, fat and fiber content, and in the production of chickens widely differing in live weight and fat content from those on the corn meal ration (10). In spite of these differences, as pointed out above, the productive energy of 100 grams of the effective digestible nutrients in the different feeds usually were within 10 percent of that of corn meal. That is to say, in spite of some wide differences in the effects of the total ration, the portion of the metabolizable energy of the individual feeds which could be utilized as productive energy was reasonably constant.

The quantity of the effective digestible nutrients is a fairly accurate measure of the energy values of chicken feeds but the productive energy is more accurate. Now that productive energy values are available, their use affords more accurate measure of the energy values of rations and individual feeds.

Definitions of Terms

Digestible nutrients are measured by the differences between the quantities of protein, ether extract, crude fiber and nitrogen-free extract in the quantity of feed fed and in the quantity of solid excrement from the quantity of food in question. In the case of chickens, which excrete the undigested food and the urinary products together, correction is made for the quantity of uric acid present. The digested nutrients, therefore, represent the difference between the nutrients consumed and those excreted. Except for the uric acid, correction was not made for the metabolic products in the chicken excrements.

Metabolizable energy is the energy of the food eaten less the energy of the excrement derived from it, both fecal and urinary, and, in the case of ruminants, in gases produced by fermentation. It represents the maximum amount of energy which the animal can secure from the feed in question. The metabolizable energy of chicken feeds is discussed in Bulletin 589 (16).

Net energy is the metabolizable energy less the energy used in utilizing it. The net energy may be used for maintenance, for the production of fat, flesh, eggs or other animal products, or body movements or work. The proportion of the metabolizable energy which can be used as net energy may depend upon the use made of it.

Productive energy is the net energy as measured by the energy stored up as fat and protein in a growing or fattening animal. The percentages of loss in utilizing the metabolizable energy may differ according to the uses made of it. Net energy may be different when used for maintenance than when used for fattening and growth or when used for work. The term productive energy is used to distinguish the net energy as measured by storage of protein and fat in a growing animal from the net energy for maintenance, or work, or for other purposes than fattening, for which the net energy value may be different.

Maintenance requirement is that portion of the energy of the food used in the life processes of the animal, for keeping the animal warm, and for movements of the body. Some individuals are more active than others, consequently they have higher maintenance requirements. The maintenance requirements are here expressed in terms of productive energy.

A therm is 1,000 large calories. A large calorie is the amount of heat required to raise the temperature of one kilogram of water to the extent of one degree centigrade.

Effective organic constituents of a feed or ration is the sum of the percentage of the protein, the fat or ether extract multiplied by 2.25, and the nitrogen-free extract. The crude fiber is considered to have no energy value for chickens.

Effective digestible nutrients of a feed or ration is the sum of the percentages of digestible protein, the digestible fat or ether extract multiplied by 2.25, and the digestible nitrogen-free extract.

Energy Production Coefficients

In our previous publications, the total energy, metabolizable energy, productive energy and the like, of poultry feeds have been discussed in terms of calories per 100 grams. For many years, however, the productive energy and net energy of cattle feeds has been expressed in therms per 100 pounds of feed (2). In order to secure uniformity, the productive energy of chicken feeds will here likewise be expressed in therms per 100 pounds of feed.

The productive energy of the feed or ration as measured by the experimental work has been reported in several different ways in previous publications, namely, in calories per 100 grams of the feed, in calories per 100 grams of the effective organic constituents, in calories per 100 grams of the effective digestible nutrients, and in percentage of the metabolizable energy (12, 15, 17, 18).

Any one of these sets of data may be used to calculate the productive energy of a feed as may be desired or as the data available may permit, but the feeds used in the experimental work did not always have the average composition. If the composition of the feed is known or assumed to be of average composition, the effective digestible nutrients can be calculated from the results of digestion experiments made on it, or from average digestion coefficients as previously given (11). Using the most probable value ascertained by experiment for productive energy of the effective digestible nutrients (18), the productive energy can be calculated in calories per 100 grams. The calories per 100 grams can then be converted to therms per 100 pounds by another calculation.

This series of calculation can be made much shorter by using the energy production coefficients which combine the calculations named above. The productive energy coefficient of a particular feed gives the calculated therms of productive energy which will be furnished by one pound of protein in that feed. Similar coefficients are given for ether extract or fat and nitrogen-free extract. Table 1 contains a calculation of the productive energy of average corn meal. The percentages in Column 1 are multiplied by the corresponding productive energy coefficients in Column 2 to secure the product in Column 3. The total of the products in Column 3 gives the productive energy of the average corn meal as 114.5 therms per 100 pounds.

Table 1. Calculation of the productive energy of corn meal.

	Percentage in feed 1.	Energy production coefficients 2.	Product therms per 100 pounds 3.
Protein	9.9	1.17	11.6
Ether extract	4.1	2.75	11.3
Nitrogen-free extract	71.6	1.28	91.6
Total			114.5

Digestion coefficients and energy production coefficients are given in Table 2. The digestion coefficients in Columns 1, 2, 3 are considered to be the most probable averages from the data in Bulletin 663 (11). The productive energy values of the effective digestible nutrients, calories per gram as given in Column 4, are the most probable values from the data in Bulletins 600, 625 and 665 (12, 17, 18).

The factor .454 was used to convert calories per gram to therms per 100 pounds. The digestion coefficients in Column 1 (protein) are multiplied by the figures in Column 4, and the products are multiplied by .435 to give the production coefficients for protein as given in Column 5. The coefficients for nitrogen-free extract in Column 7 were secured in a similar way from the data in Column 3 and the factors in Column 4. The coefficients for ether extract are secured from the data in Columns 2 and 4, but the results are also multiplied by 2.25, because ether extract was assumed to have 2.25 times the energy value of protein and nitrogen-free extract in calculating the effective digestible nutrients in the experimental work.

Composition, Productive Energy and Digestible Protein of Some Poultry Feeds

It is well known that different samples of the same kind of feed may differ in their content of protein, water, crude fiber and other constituents. On account of the impossibility of making chemical analyses of every lot of feeding stuffs, it is frequently necessary to use an assumed composition. The feed is frequently assumed to have an average composition, but sometimes a different assumption is made. Most samples of feeds will be either below or above the average composition in some respect; this is

Table 2. Digestion coefficients and energy-production coefficients of chicken feeds.

Feed	Digestion coefficients			Factor	Production coefficients		
	Protein	Ether extract	Nitrogen-free extract		Protein	Ether extract	Nitrogen-free extract
Alfalfa leaf meal	.56	.59	.37	2.40	.61	1.45	.40
Alfalfa meal	.56	.55	.34	2.40	.61	1.35	.37
Alfalfa stem meal (assumed)	.50	....	....	....	.55	1.20	.30
Artichoke tuber, Jerusalum	.67	.60	.94	2.70*	.82	1.66	1.16
Barley, no hulls	.74	.78	.80	3.00	1.01	2.39	1.09
Barley, whole	.73	.75	.80	2.70	.90	2.07	.98
Beans, lima, raw	.35	.92	.69	1.80	.29	1.69	.57
Beans, lima, cooked	.74	.74	.75	3.00	1.01	2.27	1.02
Beans, navy, raw	.42	.64	.41	3.00	.57	1.96	.56
Beans, navy, cooked	.60	.72	.66	3.00	.82	2.21	.90
Beans, pinto, raw	.43	.97	.39	1.13	.22	1.12	.20
Beans, all kinds, raw	.42	.74	.41	....	.57	2.27	.56
Beans, all kinds, cooked	.74	.74	.66	....	1.01	2.27	.90
Beef, dried	.86	.97	1.00	3.00	1.17	2.97	1.36
Beets (roots)	.69	.74	.87	3.00	.94	2.27	1.18
Beet pulp, dried	.27	.54	.23	3.00	.37	1.66	.31
Blood meal	.90	.46	.48	3.00*	1.23	1.41	.65
Bone meal	.87	.93	.34	2.60*	1.03	2.47	.40
Brewers grains	.80	.60	.78	2.70*	.98	1.66	.96
Broom corn seed	.46	.91	.82	3.00	.63	2.78	1.12
Buckwheat, grain	.61	.86	.84	2.80*	.77	2.46	1.07
Buckwheat flour	.86	.74	.89	2.80*	1.09	2.12	1.13
Buckwheat bran	.60	.67	.61	2.70*	.74	1.85	.75
Buttermilk, dried	.69	.95	.71	2.40	.75	2.34	.77
Cabbage	.72	.57	.80	2.40*	.78	1.40	.87
Cane seed	.69	.76	.90	2.70*	.85	1.90	1.11
Carrots (roots)	.68	.64	.93	2.40*	.74	1.54	1.01
Casein	.85	.48	....	3.17	1.22	1.55	....
Citrus pulp, dried	.16	.70	.42	3.00	.22	2.15	.57
Clover	.63	.61	.65	2.40*	.69	1.50	.71
Coconut oil meal	.56	.92	.32	3.00	.76	2.81	.44
Collards, dried	.70	.65	.53	2.40*	.76	1.60	.58
Corn bran	.54	.89	.33	3.00	.73	2.72	.45
Corn gluten feed	.62	.65	.44	3.00	.84	1.98	.60
Corn distillers dried solubles (assumed)	.81	....	....	....	1.10	2.00	.80
Corn gluten meal	.81	.55	.57	3.00	1.10	1.69	.78
Corn meal	.86	.90	.94	3.00	1.17	2.76	1.28

*Estimated value

Corn germ meal (assumed)	.86	....	....	....	1.17	2.75	1.28
Cottonseed flour	.73	.86	.38	3.00	.99	2.63	.52
Cottonseed hulls	0	.31	0	0	0	0	0
Cottonseed hulls, delinted	.14	.33	.5	0	0	0	0
Cottonseed meal 43% protein, 12% crude fiber	.70	.97	.36	2.80	.89	2.77	.46
Cottonseed meal 41% protein, 14% crude fiber	.63	....	....	....	.80	2.50	.42
Cottonseed meal, 38.6% protein, 18% crude fiber	.60	....	....	....	.76	2.40	.40
Cottonseed meal, 36% protein, 22% crude fiber	.57	....	....	....	.72	2.30	.36
Feterita, grain	.88	.81	.91	3.00*	1.20	2.47	1.24
Flax seed	.90	.93	.60	3.00	1.23	2.85	.82
Fish meal	.75	.83	.35	3.00*	1.02	2.54	.48
Fish meal (codfish)	.90	.90	.65	3.00	1.22	2.76	.88
Flour, clear	.90	.97	.99	2.74	1.12	2.72	1.23
Flour, graham	.75	.99	.90	2.76	.94	2.79	1.13
Flour, low grade	.84	.96	.89	2.77	1.05	2.72	1.12
Flour, patent	.86	.97	.95	2.83	1.11	2.81	1.23
Grain sorghum seed	.86	.80	.95	3.00	1.17	2.45	1.29
Grain sorghum mill feed	.75	....	....	....	1.00	2.20	1.00
Grass, young	.63	.55	.65	2.40*	.69	1.35	.71
Gelatin	.74	....	....	1.90	.64	....	....
Hegari grain	.86	.77	.95	3.00	1.17	2.36	1.29
Hemp seed	.75	.90	.65	2.70*	.92	2.48	.80
Hominy feed or meal	.81	....	....	....	1.10	1.70	1.00
Kafir grain	.80	.80	.93	3.00	1.09	2.45	1.27
Lactose	0	0	.46	.40	0	0	.08
Linseed oil meal	.62	.76	.24	3.00	.84	2.32	.33
Liver meal	.65	.91	.45	3.00	.89	2.79	.61
Macaroni	.78	.85	.97	2.80*	.99	2.43	1.23
Meat meal, meat scraps, meat and bone meal	.61	.90	.60	3.00	.83	2.76	.82
Milk, dried skim	.75	.57	.66	1.88	.64	1.10	.56
Milk sugar feed, assumed the same as dried skim milk	....	....	....	....	....	....	....
Millet seed	.70	.95	.91	3.00	.95	2.91	1.24
Milo grain	.88	.84	.97	3.00	1.20	2.58	1.32
Molasses	.60	....	....	....	.74	0	1.10
Oat hulls	.21	.74	.20	0	0	0	0
Oat meal (or groats)	.85	.93	.92	3.00	1.16	2.85	1.25
Oat meal, feeding	.80	....	....	....	1.00	2.83	1.10
Oats, whole, average	.56	.92	.66	3.00	.76	2.80	.90
Oats, whole, 20% hulls	....	....	....	....	.76	2.80	1.15
Ditto, 30% hulls	....	....	....	....	.76	2.80	.96
Ditto, 45% hulls	....	....	....	....	.76	2.80	.77
Oil, corn	....	.88	....	2.40	....	2.16	....
Oil, cottonseed	....	.89	....	2.40	....	2.18	....
Oil, medium, hydrogenated	....	.91	....	2.40	....	2.23	....
Oil, highly, hydrogenated	....	.45	....	2.40	....	1.10	....
Oil, peanut	....	.87	....	2.40	....	2.13	....
Oil, cod liver	....	.64	....	2.40	....	1.57	....

*Estimated value

Table 2. Digestion coefficients and energy-production coefficients of chicken feeds—Continued.

Feed	Digestion coefficients			Factor	Production coefficients		
	Protein	Ether extract	Nitrogen-free extract		Protein	Ether extract	Nitrogen-free extract
Oil, soybean	...	.90	...	2.40	...	2.21	...
Palm kernels	.70	.77	.77	2.80*	.89	2.20	.98
Peas, canned	.72	.40	.70	3.00	.98	1.22	.95
Peas, cowpeas, raw	.48	.88	.86	3.00	.65	2.70	1.17
Peas, blackeye, cooked	.73	.95	.83	3.00	.99	2.91	1.13
Peas, blackeye, raw	.73	.90	.76	3.00	.99	2.76	1.04
Peas, raw, all kinds	.75	.75	.79	3.00	1.02	2.30	1.08
Peanut meats	.80	.78	.84	3.00	1.09	2.39	1.14
Peanut meal (43% protein)	.74	.91	.51	3.00	1.01	2.79	.69
Peanut meal or cake, 5.1 to 10.0% crude fiber	.76	.74	.75	3.00*	1.03	2.28	1.02
Peanut meal or cake, 10.5 to 15.0% crude fiber	.70	.68	.67	2.70*	.86	1.88	.82
Peanut hay, assumed same as alfalfa stem meal	...	...	...	...	...	...	...
Potatoes, white	.57	.41	.85	2.80*	.72	1.17	1.08
Potatoes, sweet	.38	.74	.88	2.67	.46	2.02	1.07
Rape seed	.80	.86	.79	3.00*	1.09	2.64	1.07
Rice, polished	1.00	1.00	.95	3.00	1.36	3.06	1.29
Rice bran	.59	.92	.67	2.70	.73	2.54	.82
Rice hulls	0	.41	.17	0	0	0	0
Rice polishings	.77	.91	.87	3.00	1.05	2.79	1.19
Rice stone bran (assumed)	.59	...	...	...	.73	2.00	.80
Rice, rough (with hulls)	.74	.72	.84	2.70	.91	2.00	1.03
Rye seed	.66	.52	.76	2.80	.84	1.49	.97
Rutabagas	.75	.75	.90	...	...	...	...
Rye flour	.65	.61	.80	2.50	.74	1.56	.91
Sardine meal (assumed)	.75	...	...	...	1.02	2.54	.48
Shrimp meal	.59	.87	.56	3.00	.80	2.67	.76
Sesame cake, assumed to be the same as linseed oil meal	...	...	...	...	...	...	...
Sorghum seed	.66	.88	.90	3.00	.90	2.70	1.23
Soybeans	.92	.90	.69	2.70	1.13	2.50	.85
Soybean oil meal, average fat and quality	.74	.79	.34	2.70	.91	2.18	.42
Soybean oil meal, low fat	.75	.38	.30	2.70	.92	1.05	.37
Soybean oil meal, cooked at low temperature	.54	.41	.26	2.70*	.66	1.13	.32
Starch	...	...	.97	2.60	...	...	1.14
Sugar beet, leaves	.74	.25	.89	2.40*	.81	.61	.97
Sugar beet, roots	.70	.78	.91	2.40*	.76	1.91	.99
Sugar, sucrose	...	...	.67	3.00	...	...	.91
Sunflower seed	.66	.95	.16	3.00	.90	2.91	.22
Sunflower seed cake	.77	.82	.86	3.00	1.05	2.52	1.17
Tapioca meal	.86	.85	.87	2.70*	1.06	2.35	1.07
Tankage	.55	.88	.90	2.60	.65	2.34	1.06

Table 2. Digestion coefficients and energy-production coefficients of chicken feed—Continued

Feed	Digestion coefficients			Factor	Production coefficients		
	Protein	Ether extract	Nitrogen-free extract		Protein	Ether extract	Nitrogen-free extract
Turnip, roots	.68	.74	.91	2.40*	.74	1.82	.99
Wheat, whole grain	.93	.96	.95	2.70	1.14	2.65	1.17
Wheat, soft	.74	.47	.89	2.70	.91	1.30	1.09
Wheat bran	.59	.86	.37	2.70	.73	2.39	.46
Wheat bran (human food)	.57	.76	.63	2.70	.69	2.10	.77
Wheat brown shorts (assumed)	.60	....	....	....	.74	2.40	.60
Wheat mixed feed (assumed)	.63	....	....	....	.80	2.40	.70
Wheat gray shorts	.68	.86	.63	2.80	.86	2.46	.80
Wheat white shorts or red dog	.90	....	....	....	1.10	2.60	1.10
Wheat germ (assumed)	.68	....	....	....	.86	2.48	.80
Whale meal	.85	.90	.60	3.00*	1.16	2.76	.82
Whey, dried, assumed the same as dried skim milk	....	....	....	....	....	....	....
Yeast	.69	.48	.54	2.00	.63	.98	.49

*Estimated value

due to the nature of an average. For the purpose of making guarantees under feed laws, so as to allow margins for variations, feeds may be assumed to have a composition lower than the average used for protein, fat and nitrogen-free extract, and higher than the average for crude fiber. These are termed the minimum guarantees. Such minimum guarantees are also used in calculating the composition to be guaranteed for mixtures sold under the feed law, when the ingredients are of average quality.

The average chemical compositions and the minimum guarantees of a number of chicken feeds are given in Table 3. Most of these are averages compiled from analyses made in this Division, from samples collected by the Feed Control Service, or for other purposes. Some of the feeds given are not used in commercial feeds sold in Texas.

The minimum guaranteed compositions given in Table 3 are marked min. The figures for minimum guarantees not marked with an asterisk are the minimum guarantees permitted by the Texas Feed Control Service (4). Those figures marked with an asterisk are the estimated minimums for the constituents so marked.

The productive energy and the digestible protein in Table 3 were calculated by means of the production coefficients and coefficients of digestibility for protein given in Table 2.

Commercial grains, especially corn and grain sorghums, often contain more water than is present in the averages of the commercial feeds shown in Table 3, in which it is around 10 percent. Commercial grade No. 1 of corn or grain sorghums may contain 14 percent water (21). Corn of grade No. 2 may contain more than 15.5 percent; Grade No. 3 may contain 17.5 percent, No. 4, 20 percent, and No. 5, 23 percent. Grain sorghums of grade No. 2 may contain 15 percent water, Grade No. 3, 16 percent, and Grade No. 4, 18 percent. Higher percentages of water than those shown for the averages in Table 3 correspondingly decrease the other constituents, and consequently the digestible protein and productive energy is lower. Over 12 percent water in corn chops or similar feeds may cause heating and consequent damage (5) especially in warm weather. Table 3 contains the composition, productive energy and digestible protein for corn and grain sorghum of different water contents, calculated from the average composition.

Grains such as oats and barley vary in the proportions of kernels to hulls (3). As shown in Table 3 the kernel has a high feeding value, while the hull has practically no feeding value for chickens, although it may furnish bulk. To a certain extent, but not completely, the weight per bushel is an index to the feeding value of such grains. Titus (24) states that extra heavy oats are to be preferred for use of poultry, and many experts recommend the use of heavy oats when oats are used for feeding chickens. Table 3 contains the composition, digestible protein and productive energy of oats containing 20 percent, 30 percent, and 45 percent oat hulls, calculated by means of the average composition of oat hulls and oat groats given in Table 3.

Table 3. Average composition, minimum guarantee, productive energy and digestible protein of some poultry feeds.

	Protein %	Ether extract %	Crude fiber %	Nitrogen-free extract %	Water %	Ash %	Productive energy therms per 100 pounds	Digestible protein percent
Alfalfa leaf meal	20.3	2.6	18.4	38.2	7.5	13.0	31.4	11.4
Ditto, min	18.0*	2.5*	18.0	38.0*	....	....	30.8	10.1
Alfalfa meal	15.6	2.0	27.2	37.4	8.0	9.8	26.1	9.1
Ditto, min	13.0	1.5	33.0	35.0*	....	....	22.9	7.3
Alfalfa stem meal	11.8	1.3	36.1	34.7	8.6	7.5	18.5	5.9
Artichoke tuber, dried	9.9	0.4	4.3	78.4	2.1	4.9	99.6	5.0
Artichoke tuber, Jerusalem	2.2	0.1	0.8	14.6	80.8	1.5	18.9	1.1
Babassu oil meal	23.5	6.8	11.8	46.3	6.5	5.1	50.8	14.6
Barley, no hulls	13.7	1.0	1.0	72.0	9.6	2.7	94.7	10.1
Barley, whole	13.1	2.1	6.0	66.3	9.4	3.1	81.1	9.6
Ditto, min	11.0*	1.5*	6.0	65.0*	....	....	76.7	8.0
Beans, all kinds, raw	24.0	1.2	4.5	58.0	8.3	4.0	48.9	10.1
Beans, all kinds, cooked	24.0	1.2	4.5	58.0	8.3	4.0	79.2	17.8
Beets, (roots)	18.3	0.4	6.9	61.9	3.4	9.1	91.2	12.6
Beet pulp, dried	9.2	.5	20.7	57.4	9.1	3.1	22.0	2.5
Blood meal	79.4	1.2	1.5	2.8	9.6	5.5	100.4	71.5
Blood meal, solvent process	30.4	1.4	1.2	2.9	5.1	59.3	35.9	26.5
Bone meal, (raw)	24.0	6.0	1.2	3.9	5.7	59.2	41.1	20.9
Ditto, min	23.0	5.0*	3.0	0	6.6	62.4	36.0	20.0
Bone meal, steamed	25.3	3.6	1.2	1.5	6.6	62.4	30.0	22.3
Bone meal, special steamed	8.6	4.0	2.5	3.4	2.8	78.7	20.2	7.5
Brewers grains, dried	25.3	6.5	16.4	40.1	7.8	3.9	100.5	20.2
Broom corn seed	9.9	2.3	12.4	61.9	7.4	6.1	82.0	4.6
Buckwheat seed	11.0	2.3	12.9	62.2	9.9	1.7	70.0*	6.0*
Buckwheat flour	11.2	2.4	0.7	73.6	6.5	10.2	93.3	6.8
Buttermilk, dried	34.1	6.3	0.4	39.5	8.0	11.7	70.7	23.5
Ditto, min	32.0*	5.0	0.5*	35.0	....	....	68.0	22.1
Buttermilk, condensed	10.6	2.7	0.2	12.8	69.4	4.3	24.1	7.3
Ditto, min	10.0*	2.0	0.2	10.0*	....	....	19.9	6.9
Cabbage, (dried)	20.0	1.4	11.2	51.8	5.9	9.7	62.6	12.4
Cane seed (red top)	7.8	4.3	2.5	72.2	11.6	1.6	94.9	5.4
Carrots, (roots), dried	9.0	1.2	8.9	67.9	5.1	7.9	77.1	6.1
Casein	81.9	0.1	0.2	3.3	10.6	3.9	101.6	69.7
Citrus pulp, dried	5.6	2.3	10.0	63.7	10.5	7.0	42.4	0.9
Clover (hay red)	11.8	2.6	27.3	40.1	11.8	6.4	40.5	7.4
Coconut oil meal	20.5	9.4	11.1	45.2	6.7	7.1	61.9	11.5
Collards, dried	30.0	4.5	12.5	29.0	4.5	19.5	46.8	21.0
Corn, corn meal or chops	9.9	4.1	2.1	71.6	10.9	1.4	114.5	8.5
Ditto but 13% water	9.7	4.0	2.0	69.9	13.0	1.4	111.8	8.3
Ditto 15% water	9.4	3.9	2.0	68.4	15.0	1.3	109.2	8.1

Table 3. Average composition, minimum guarantee, productive energy and digestible protein of some poultry feeds—Continued

	Protein %	Ether extract %	Crude fiber %	Nitrogen-free extract %	Water %	Ash %	Productive energy therms per 100 pounds	Digestible protein percent
Ditto 16.5% water	9.3	3.8	2.0	67.1	16.5	1.3	107.3	8.0
Ditto 19% water	9.0	3.7	1.9	65.1	19.0	1.3	104.1	7.7
Corn, corn meal or chops, min	9.0	3.5	3.0	70.0*	10.9	1.8	114.5	8.7
Corn bran	10.6	7.6	8.1	61.8	9.3	2.6	56.2	5.7
Ditto, min	8.0	5.0	12.0	60.0			46.4	4.3
Corn distillers dried solubles	27.0	7.0	1.0	52.0	5.0	8.0	85.3	22.0
Corn feed meal	10.1	4.9	2.6	69.7	10.9	1.8	114.5	8.7
Ditto, min	8.0	3.0	3.0	67.0*			103.5	6.9
Corn germ meal	23.3	7.3	10.5	49.8	7.0	2.1	111.1	20.0
Corn gluten feed	26.9	2.7	7.4	47.5	9.2	6.3	56.5	16.7
Corn gluten meal	44.6	2.7	3.0	38.8	8.8	2.1	83.9	36.1
Corn oil meal	23.8	6.2	10.4	48.1	8.6	2.9	106.5	20.5
Cottonseed hulls	4.1	0.9	47.6	35.3	9.4	2.7	0	0
48% protein cottonseed meal, min	48.0	7.0	9.0	26.0*			74.1	33.6
45% protein cottonseed meal, min	45.0	6.0	10.0	22.0*			66.8	31.5
Cottonseed meal 43% protein	42.9	6.8	10.6	27.0	6.9	5.8	69.4	30.0
Ditto, min	43.0	5.7	12.0	24.0			66.8	31.5
Cottonseed meal 41% protein	40.7	6.1	11.4	27.8	7.8	6.2	65.9	28.5
Ditto, min	41.0	5.0	12.0	26.0			62.4	28.7
Cottonseed feed 41.12% protein	41.1	6.0	10.9	28.0	7.5	6.5	66.0	28.7
Feterita, grain	12.7	2.8	2.5	69.3	10.7	1.7	108.1	11.2
Feterita chops, min	11.0	2.5	3.0	68.0*			103.7	9.7
Flax seed	23.5	36.4	5.9	24.2	6.4	3.0	155.5	21.2
Fish meal, 64% protein	67.3	4.3	0.4	5.8	7.8	14.4	89.8	50.5
Fish meal, 68% protein	68.6	4.8	0.4	5.5	7.2	13.8	92.1	51.2
Fish meal, 72% protein	72.6	6.0	0.6	1.9	6.8	12.2	98.3	54.4
Flour, graham	12.4	1.8	1.8	70.3	12.3	1.4	96.3	9.3
Grain sorghum seed (milo, kafir, etc.)	11.2	3.0	2.4	70.6	10.8	2.0	111.5	9.6
Ditto but 13% water	10.9	2.9	2.3	68.8	13.0	2.0	108.7	9.4
Ditto 15% water	10.7	2.9	2.3	67.3	15.0	1.9	106.3	9.1
Ditto 17% water	10.4	2.8	2.2	65.7	17.0	1.9	103.7	8.9
Grain sorghum mill feed	10.2	5.6	3.3	66.4	11.5	3.0	88.9	7.7
Grass, young, dried	14.1	2.3	19.4	43.2	10.0	11.0	43.5	8.9
Hegari grain	11.1	2.2	2.3	69.3	11.6	3.5	104.8	9.6
Hempseed oil meal	31.1	6.6	22.8	23.3	8.2	8.0	67.0	23.3
Hominy feed or meal	11.0	7.2	6.4	63.0	9.4	3.0	86.6	8.9
Ditto, min	10.0	5.0	7.0	60.0*			79.5	8.1
Hominy feed, low fat	12.7	5.8	5.8	61.8	10.4	3.5	85.1	10.3
Kafir grain or chops	11.8	2.7	2.2	70.1	11.0	2.2	107.8	9.4
Ditto, min	10.0	2.5	3.0	69.0			104.0	8.0

Linseed oil meal, 32% protein	32.6	7.6	9.0	36.0	9.0	5.8	56.9	20.2
Linseed oil meal, 34% protein	36.1	5.9	8.5	35.0	8.8	5.7	55.6	22.4
Linseed oil meal, 37% protein	38.7	6.5	7.4	33.2	8.6	5.6	58.6	24.0
Liver meal	63.8	18.3	1.0	3.2	8.6	5.1	109.2	41.5
Meat and bone scraps, 45% protein	47.3	12.3	2.1	1.7	6.5	30.1	74.5	28.9
Meat and bone scraps, 50% protein	51.0	10.5	2.1	1.5	6.3	28.6	72.4	31.1
Meat and bone scraps, 55% protein	57.6	8.0	2.9	3.2	6.3	22.0	72.4	35.1
Meat and bone scraps, 60% protein	59.6	8.8	1.5	0.7	6.9	22.5	74.2	36.4
Meat scraps or meal, 60% protein	61.2	11.8	3.2	1.7	6.2	15.9	84.7	37.3
Meat scraps or meal, 65% protein	67.2	11.9	2.0	2.6	5.9	8.4	91.0	42.2
Meat meal, min	65.0	6.0	3.0*	2.0*	...	...	72.1	39.7
Milk, dried skim	35.0	1.1	.2	50.1	5.6	8.0	52.5	26.3
Milk sugar feed	12.0	.7	.3	73.0	3.7	10.3	50.2	9.0
Millet seed	10.5	3.9	10.0	62.3	9.7	3.6	98.5	7.4
Milo grain	11.8	3.0	2.3	70.1	10.7	2.1	114.4	10.4
Milo chop, min	10.0	2.5	3.0	69.0*	...	...	109.5	8.8
Molasses	3.3	0	0	63.1	27.3	6.3	71.4	2.0
Oat hulls	4.6	1.4	30.2	50.7	6.5	6.6	0	0.9
Oat meal or groats	17.0	6.6	2.0	62.6	9.7	2.1	116.7	14.5
Oat meal or flakes, feeding	10.2	6.2*	3.0	63.4	9.0	2.3	115.5	13.7
Oat meal, feeding, min	16.0	6.0	4.0	62.0	...	...	113.0	13.6
Oats, whole, average	12.0	5.0	10.9	58.8	9.3	4.0	76.0	6.7
Oats, whole, 20% hulls	14.5	5.6	7.6	60.2	8.7	3.4	93.4	11.8
Oats, whole, 30% hulls	13.3	5.0	10.5	59.0	8.5	3.7	81.7	10.4
Oats, whole, 45% hulls	11.4	4.3	14.7	57.3	8.1	4.2	64.2	8.4
Oil, cottonseed	0	100.0	0	0	0	0	218.0	...
Oil, corn	0	100.0	0	0	0	0	210.0	...
Peas, raw	24.0	1.0	3.0	58.0	10.5	3.5	88.8	18.0
Peas, cooked	24.0	1.0	3.0	58.0	10.5	3.5	91.7	18.0
Peanut meal, 48% protein min	48.0	7.0	9.0	22.0*	...	...	87.8	36.5
Peanut meal, 43% protein	43.8	8.0	11.6	24.8	6.1	5.7	73.1	30.7
Ditto, min	43.0	6.0	12.0	23.0*	...	...	66.9	30.1
Peanut meal, 45% protein	44.4	7.6	13.9	22.6	7.2	4.3	86.1	33.7
Ditto, min	45.0	6.0	10.0	22.0*	...	...	86.8	34.2
Peanut hay, ground	10.0	3.2	22.3	43.5	9.7	11.3	22.4	5.0
Potatoes, white, dried	11.5	0.3	2.1	75.0	6.6	4.5	89.6	6.6
Potatoes, sweet, dried	4.5	1.2	3.5	82.0	5.3	3.5	92.2	1.7
Rape seed oil meal	34.8	5.1	11.7	30.4	10.0	8.0	86.4	27.8
Rice polished	8.8	0.4	0.4	77.3	12.5	0.6	105.0	8.8
Rice bran	12.8	14.1	12.8	38.9	8.5	12.9	77.1	7.6
Ditto, min	11.0	10.0	15.0	40.0*	...	...	66.2	6.5
Rice hulls	3.1	0.9	40.1	28.9	8.1	18.9	0	0
Rice polishings	12.8	13.0	3.1	52.6	9.9	8.6	103.7	9.9
Ditto, min	11.0	6.0	4.0	52.0	...	...	93.0	8.5
Rice stone bran	11.2	10.7	16.8	36.8	8.8	15.7	59.0	6.6
Rice rough with hulls	8.0	1.4	8.5	65.6	11.7	4.8	77.7	6.0
Rye chops	13.0	1.7	2.4	69.6	11.3	2.0	81.0	8.6
Rye seed	13.8	1.5	2.5	70.0	10.4	1.8	81.7	9.1
Sardine meal, 65% protein	67.3	4.5	0.5	5.4	7.2	15.2	82.6	50.4
Sardine meal, 68% protein	68.2	4.0	0.3	5.3	7.4	14.8	82.3	51.2

Table 3. Average composition, minimum guarantee, productive energy and digestible protein of some poultry feeds—Continued.

	Protein %	Ether extract %	Crude fiber %	Nitrogen-free extract %	Water %	Ash %	Productive energy therms per 100 pounds	Digestible protein percent
Shrimp meal, 50% protein	48.3	3.2	11.8	.7	9.7	26.3	47.7	28.5
Sesame cake	41.6	12.5	6.4	20.1	6.1	13.5	70.6	25.8
Soybean oil meal, 41% protein	43.9	5.5	5.8	29.9	9.2	5.9	64.9	32.5
Soybean oil meal, 43% protein	43.9	6.8	5.9	29.1	7.9	6.4	67.4	32.5
Soybean oil meal solvent process, low fat	46.0	0.7	5.7	31.9	9.8	5.9	56.5	34.0
Sunflower seed	18.5	26.0	32.0	14.5	5.8	3.2	95.0	12.2
Sunflower seed oil cake	34.8	18.3	10.9	21.8	10.0	4.2	110.0	26.8
Tankage, 40% protein	42.4	11.8	2.5	3.3	5.4	34.6	52.5	23.3
Tankage, digester, 50% protein	52.9	12.9	2.2	1.7	6.2	24.3	71.0	29.1
Tankage, digester, 60% protein	60.5	8.8	2.1	2.1	7.5	17.2	67.6	33.3
Turnip, roots, dried	12.3	0.8	11.7	59.8	4.8	10.6	69.4	8.4
Wheat grain, chops, Texas	16.7	1.9	2.7	66.0	10.4	2.5	101.3	15.5
Wheat, grain, U. S., average	13.5	2.1	2.4	69.8		1.8	102.4	12.6
Wheat chops, min	12.0	2.0	3.0	68.0*			98.6	11.2
Wheat bran	17.3	4.3	9.1	54.1	9.3	6.0	47.8	10.2
Ditto, min	14.5	3.0	10.0	50.0*			40.8	8.6
Wheat bran and scourings	17.1	4.0	9.2	52.9	10.4	6.4	46.4	10.1
Wheat bran and screenings	17.2	4.3	9.4	53.6	9.5	6.0	47.5	10.2
Wheat brown shorts	17.7	4.5	6.2	57.0	10.4	4.2	58.1	10.5
Ditto, min	15.0	3.5	7.5	53.0*			51.3	9.0
Wheat brown shorts and screenings	17.5	4.3	6.9	56.0	10.8	4.7	56.9	10.5
Wheat mixed feed	18.2	3.6	6.7	56.9	10.1	4.5	63.0	11.5
Ditto, min	15.0	3.5	8.5	52.0*			56.8	9.5
Wheat mixed feed and screenings	17.7	3.9	7.0	56.6	9.9	4.9	63.1	11.2
Wheat germs	32.1	9.2	3.2	40.9	9.4	5.2	83.2	21.8
Wheat gray shorts	18.0	4.4	5.7	57.0	10.7	4.2	72.0	12.2
Ditto, min	15.0	3.5	6.0	55.0			65.6	10.2
Wheat gray shorts and screenings	18.0	4.3	5.9	56.7	10.8	4.3	71.5	12.2
Wheat white shorts	16.2	2.9	2.2	66.3	10.3	2.1	98.3	14.6
Ditto, min	14.5	3.0	3.5	63.0*			94.1	13.1
Wheat red dog	16.1	2.5	2.6	66.3	10.1	2.2	102.0	14.5
Wheat red dog, min	12.0	2.0	4.0	66.0			91.0	10.8
Whey, dried	12.8	.7	.2	70.0	5.9	10.4	49.0	9.6
Yeast, dried	47.0	1.8	3.3	33.0	6.6	8.3	47.6	32.4

Cottonseed hulls, peanut hulls and rice hulls have no feeding values to chickens. They are present in cottonseed meal, peanut meal, and rice bran, the percentage of crude fiber being an indication of the quantity of hulls present. Such feeds should be selected with as low a percentage of crude fiber as possible.

Other factors which affect the composition and consequently the productive energy values are discussed in Bulletin 461 (8). In general it may be said that chicken feeds are not as variable in composition and productive energy as are feeds for ruminants.

As shown in Table 3, oils have the highest productive energy, about 210 therms per one hundred pounds and are sometimes added to finishing rations. Corn and oat groats have values of about 100 to 115 therms per 100 pounds, depending on the moisture content. Grain sorghums, including milo, kafir, feterita, and the like, have slightly lower values, and wheat, brewer's grains and rice polishings have about 10 percent lower values than corn or oat groats.

Fish meal, meat scraps and sunflower seed have productive energy values of approximately 90 therms. Barley (whole), broom corn seed, corn gluten meal, whole oats, rye, rice bran and sardine meal, have productive energy values of about 80 therms per 100 pounds.

Dried buttermilk, sesame oil meal, cottonseed meal, tankage, peanut meal, meat and bone scraps, wheat gray shorts and ordinary soybean meal have productive energy values of about 70 therms per 100 pounds. On account of the low oil content of solvent process soybean meal, its productive energy is about 57 therms per 100 pounds.

Corn gluten feed, dried skim milk, milk sugar feed, linseed oil meal and dried whey have productive energy values around 50 to 56 therms per 100 pounds.

Wheat bran has a productive energy of around 46 therms, young grass and clover about 40, alfalfa meal and raw bone meal around 30, special bone meal about 20, cottonseed hulls, oat hulls and rice hulls about zero.

Most of the feeds named above have feeding values in addition to their content of productive energy and digestible protein.

The term grain sorghum is similar to the terms "corn" or "wheat", and includes over 200 varieties. Commercial varieties change from year to year, new varieties being introduced and taking the place of older ones. It is often not possible to tell from examining the seed which variety of grain sorghum it is. According to the Handbook of Official Grain Standards of the United States (21), commercial grain sorghums are divided into five classes, as follows: Class I, White Grain Sorghums; Class II, Yellow Grain Sorghums; Class III, Red Grain Sorghums; Class IV, Brown Grain Sorghums; and Class V, Mixed Grain Sorghums.

Constituents and Digestibility of the Nitrogen-Free Extract

Poultry feeds, as a general rule, contain high percentages of easily digested carbohydrates or of protein. Table 4 shows the composition of the nitrogen-free extract of certain feeds (7) and Table 5 shows the digestibility.

In corn, grain sorghums, hulled barley, oat groats, rice and wheat, most of the nitrogen-free extract consists of starch, with small amounts of sugars (7). Whole oats, whole barley, rough rice and rice polish are high in starch, but contain less than the grains mentioned above, on account of the presence of the hulls or of hull particles; they also contain higher percentages of pentosans and crude fiber than the grains mentioned above. Rice bran and wheat gray shorts contain still less starch and higher percentages of pentosans, while wheat bran may contain little starch. Sugars and starches (Bul. 437, Table 5) (7) are almost completely digested by chickens. The pentosans and residual nitrogen-free extract have lower digestibilities (Table 5) but are present in comparatively small amounts in most of the chicken feeds.

Productive Energy and Digestible Protein of Some Poultry Rations

Productive energy and digestible protein of a mixed chicken feed may be calculated by use of the values for the feed ingredients given in Table 3, or, if the composition of the ingredients used is known, the productive energy and digestible protein of the individual feeds may be calculated by use of the factors in Table 2. The values so secured may be used in the calculation of the values for the ration. An example of the calculation of the productive energy and digestible protein of a ration is given in Table 6.

Mixtures to be used for feeding chickens at various periods of life and for various purposes have been recommended by a number of workers. The productive energy values and digestible protein have been calculated for a number of mixtures suggested by R. M. Sherwood, (23), Titus, Hammond, and Whitson (26) and by Almquist, Jukes and Newlon (1).

Composition of the rations to a certain extent will, of course, depend upon the composition of the feeds selected. As a rule, the constituents of the ration were assumed to have the average composition of the feeds as given in Table 3. The whole oats used were considered better than the average, because heavy oats is recommended, and to have the composition of whole oats containing 30 percent hulls, as given in Table 3.

The productive energy and digestible protein for the mixtures considered are shown in Table 7. In case of a mash to be fed with grain, the values of the total diet were also calculated, using the amount of grain mixture specified, with the assumed composition given in Table 3. The averages for the different rations are summed up in Table 8.

The average productive energy, in therms per 100 pounds, was 81.6 for all-mash chicken starter, 87.9 for all-mash growing diet and 91.7 for mash

Table 4. Constituents of the nitrogen-free extract of feeds.

Lab. No.	Name of feed	Reducing sugar %	Polysaccharoses %	Starch %	Pentosans in NFE %	Residual NFE %	Total pentosans %	Pentosans in C. F. %
20714	Alfalfa	2.20	2.40	1.20	9.09	25.63	12.62	3.53
22186	Barley	.78	1.19	47.15	9.10	11.52	10.18	1.08
20567	Corn meal	.38	.42	61.48	2.21	12.91	2.38	.17
25993	Cottonseed meal	.89	.38	0	10.00	15.74	11.71	1.71
23040	Cowpeas	.09	5.80	22.88	4.33	25.92	4.84	.57
19851	Darso seed	.55	.57	59.78	3.59	7.01	3.91	.32
24711	Spur feterita	.65	.31	55.31	3.44	10.69	3.63	.19
24854	Standard blackhull kafir	.48	.69	57.48	4.12	8.44	4.35	.23
22196	Millet	.83	.36	46.80	5.17	9.17	6.52	1.35
22168	Dwarf yellow milo	.60	.76	59.40	4.16	7.44	4.38	.22
24846	Dwarf yellow milo	.56	.76	58.66	3.62	6.83	3.78	.16
19416	Oats, whole	.98	1.02	38.50	10.91	9.58	12.31	1.40
19426	Rolled oats, groats	.08	1.39	55.30	3.67	4.74	3.67	0
20843	Rice	.41	.61	68.83	2.29	4.41	2.29	0
23087	Rice bran	2.20	5.39	8.00	9.14	13.18	10.94	1.80
23115	Rice polish	1.28	5.04	38.13	3.48	7.99	3.68	.20
22218	Rye	1.56	3.39	50.35	9.63	7.03	9.88	.25
21969	Shallu	.42	.19	54.98	3.45	8.59	3.45	0
22257	Soybeans	.23	8.26	.85	4.25	8.84	4.61	.36
24681	Sumac sorghum	.54	.56	51.03	3.56	16.74	3.76	.20
21930	Wheat	.66	1.52	49.05	7.83	9.16	8.10	.27
20193	Wheat bran	1.74	2.50	15.41	21.23	11.49	22.03	.80
23159	Wheat gray shorts	.83	5.34	35.20	14.03	1.82	14.48	.45
24384	Wheat gray shorts	1.12	5.32	23.95	12.79	13.10	13.23	.44

Table 5. Average coefficients of digestibility of sugars, starch, pentosans and residual nitrogen-free extract for chickens.

Name of deed	Number averaged	Reducing sugar	Polysaccharoses	Starch	Pentosans in NFE	Residual NFE	Total pentosans	Pentosans in C. F.
Alfalfa meal	2	81.8	97.4	63.8	2.1	40.0	16.9	49.2
Barley	10	72.5	88.2	98.5	23.6	60.6	24.4	27.7
Japanese buckwheat	2	97.4	71.9	99.3	44.7	23.0	41.1	30.9
Corn meal	18	92.6	97.3	99.0	52.3	74.6	50.5	22.1
Cottonseed meal	6	47.6	82.9	....	62.3	64.2	63.0	37.3
Cowpeas	2	0*	99.7	98.7	64.7	98.1	61.3	50.0
Darso	6	89.6	92.1	99.4	59.6	47.0	57.5	34.0
Feterita	10	97.5	94.9	99.1	50.9	60.0	49.9	30.2
Kafir	6	95.8	97.2	99.1	36.0	77.2	35.6	27.9
Millet	2	100.0	98.8	98.6	20.5	61.9	24.7	43.2
Dwarf yellow milo	13	89.5	87.9	99.3	44.3	65.1	42.5	23.0
Rolled oat groats	2	0*	96.4	99.5	80.3	74.7	79.2	0
Whole oats	3	85.1	85.5	97.2	18.0	45.9	20.0	34.3
Whole rice	4	99.0	97.1	99.7	37.8	76.2	44.0	0
Polished rice	4	99.8	79.1	99.3	79.0	98.1	80.7	50.0
Rice bran	4	96.8	96.6	90.8	7.0	9.0	8.7	22.5
Rice polish	2	91.5	93.4	98.5	34.6	29.5	31.0	0
Rye	2	95.5	92.0	98.3	58.0	52.8	57.0	16.0
Shallu	3	91.9	100.0	99.3	39.2	81.2	34.3	33.0
Soy beans	2	50.0*	97.9	....	60.4	78.3	56.8	13.9
Sumac sorghum	7	89.7	97.7	99.1	53.6	57.5	48.4	27.7
Wheat	4	78.9	93.7	98.8	49.7	77.3	45.5	6.3
Wheat bran	4	76.7	93.6	93.9	26.2	26.6	23.1	25.0
Wheat gray shorts	4	84.9	91.2	94.5	36.6	30.1	36.3	27.7
Average	....	86.5	92.6	96.5	43.4	58.7	43.0	28.5

*This sample very low in sugar.

Table 6. Calculation of the productive energy and digestible protein of a ration.

Ingredients	Ingredients. Pounds per 100 of ration	Productive energy. Therms per one pound of ingredient	Productive energy. Therms in the quantity of the ingredient used	Digestible protein. Pounds in one pound of ingredient	Digestible protein. Pounds in the quantity of the ingredient used
Ground yellow corn	43	1.145	49.2	.085	3.7
Wheat gray shorts	20	.720	14.4	.122	2.4
Pulverized whole oats, 30% hull	10	.817	8.2	.067	0.7
Fish meal (64% protein)	6	.921	5.5	.505	3.0
Soybean oil meal, 43% protein	6	.674	4.0	.325	2.0
Cottonseed meal, 43% protein	6	.694	4.2	.300	1.8
Dehydrated alfalfa leaf meal	5	.314	1.6	.114	0.6
Oyster shell, finely ground	2	0	0	0	0
Bone meal, steamed	1.5	.304	0.5	.223	0.3
Salt	0.5				
Fortified fish liver oil	1/8				
Total—Productive energy of ration in therms per 100 pounds			87.6		
Digestible protein in pounds per 100					14.5

Table 7. Productive energy and digestible protein of some recommended rations.

	Productive energy, therms per 100 lbs.	Digestible protein, %
All mash chicken starter		
Sherwood, No. 1	87.4	14.7
Ditto, No. 2	86.1	13.3
Titus et al., No. 1	81.9	18.3
Ditto, No. 2	71.5	17.5
Ditto, No. 3	86.4	17.7
Ditto, No. 4	83.9	17.6
Ditto, No. 5	80.5	19.1
Ditto, No. 6	85.0	17.5
Almquist et al., No. 1	80.2	17.5
Ditto, No. 2	79.6	14.7
Ditto, No. 3	75.3	15.7
Average (11)	81.6	16.7
Grain mixture: whole oats 30%, corn 40%, grain sorghum 30%	104.2	9.4
Chick growing mash to be fed with grain—2 of mash to 5 of grain, Sherwood: equal weight of grain, Titus.		
Sherwood, No. 5	53.6	20.5
Ditto, No. 6	53.6	19.5
Titus et al., No. 1	82.9	17.3
Ditto, No. 2	74.2	16.8
Ditto, No. 3	83.5	18.3
Ditto, No. 4	80.6	18.4
Ditto, No. 5	79.2	20.4
Ditto, No. 6	80.9	17.9
Average (6) Titus only	80.2	18.2
Chick growing mash (above) fed with grain mixture (above)		
Sherwood, No. 5	89.7	12.6
Ditto, No. 6	89.7	12.3
Titus et al., No. 1	93.6	13.9
Ditto, No. 2	89.7	13.1
Ditto, No. 3	93.9	13.9
Ditto, No. 4	92.4	13.9
Ditto, No. 5	91.6	14.9
Ditto, No. 6	92.6	13.6
Average (8)	91.7	13.5
All mash chick growing diet		
Sherwood, No. 1	91.4	12.4
Ditto, No. 2	91.9	12.0
Titus et al., No. 1	89.0	14.3
Ditto, No. 2	73.0	14.9
Ditto, No. 3	91.5	15.3
Ditto, No. 4	90.9	15.5
Ditto, No. 5	86.7	16.7
Ditto, No. 6	89.1	13.7
Average (8)	87.9	14.4
Laying mash to be fed with grain; 1 of mash to 2 of grain, No. 9 and 10 Sherwood; equal weight, Titus and Almquist, and Sherwood No. 7 and 8.		
Sherwood, No. 9	63.2	21.1
Sherwood, No. 10	59.9	16.8
Sherwood, No. 7	76.1	15.9
Sherwood, No. 8	74.2	13.7
Titus et al., No. 1	72.1	17.5
Ditto, No. 2	66.8	18.0
Ditto, No. 3	76.1	16.7
Ditto, No. 4	70.7	17.8
Ditto, No. 5	66.1	18.1
Ditto, No. 6	73.0	17.3

Table 7. Productive energy and digestible protein of some recommended rations —Continued.

	Productive energy, therms per 100 lbs.	Digestible protein, %
Almquist et al., No. 1	79.6	15.5
Ditto, No. 2	83.7	15.3
Ditto, No. 3	85.2	18.8
Ditto, No. 4	73.6	15.2
Average (14)	73.0	17.0
Laying mash, above, plus grain mixture, above.		
Sherwood, No. 7	90.2	12.7
Sherwood, No. 8	89.2	11.6
Sherwood, No. 9	90.5	13.3
Ditto, No. 10	89.4	11.8
Titus et al., No. 1	88.1	13.5
Ditto, No. 2	85.5	13.7
Ditto, No. 3	90.2	13.1
Ditto, No. 4	87.5	13.6
Ditto, No. 5	85.1	13.8
Ditto, No. 6	88.9	13.4
Almquist et al., No. 1	91.9	12.5
No. 2	94.0	12.4
No. 3	94.7	14.1
No. 4	88.9	12.1
Average (14)	89.5	12.9
All-mash laying ration		
Titus et al., No. 1	84.3	13.3
Ditto, No. 2	83.4	14.2
Ditto, No. 3	86.0	13.6
Ditto, No. 4	79.6	14.3
Ditto, No. 5	78.6	16.8
Ditto, No. 6	84.6	14.3
Almquist, Table 9	85.4	12.8
Average (7)	83.1	14.2
Breeding diet to be fed with an equal weight of grain		
Titus et al., No. 1	71.3	16.4
Ditto, No. 2	66.0	16.8
Ditto, No. 3	73.1	17.4
Ditto, No. 4	66.4	17.6
Ditto, No. 5	63.7	18.5
Ditto, No. 6	71.6	17.5
Average (6)	68.7	17.4
Breeding diet fed with an equal weight of grain		
Titus et al., No. 1	87.8	12.9
Ditto, No. 2	85.1	13.1
Ditto, No. 3	88.7	13.4
Ditto, No. 4	85.3	13.5
Ditto, No. 5	83.9	14.0
Ditto, No. 6	87.9	13.5
Average (6)	86.5	13.4
All mash breeding diets		
Titus et al., No. 1	81.5	13.0
Ditto, No. 2	83.5	13.5
Ditto, No. 3	83.5	13.1
Ditto, No. 4	76.9	14.2
Ditto, No. 5	79.0	16.3
Ditto, No. 6	83.8	14.4
Average (6)	81.4	14.1

Table 8. Summary of averages for productive energy and digestible protein in chicken diets.

	Productive energy, therms per 100 lbs.	Digestible protein, %
All mash chicken starter (11)	81.6	16.7
Grain mixture	104.2	9.4
Chick growing mash to be fed with equal parts of grain (6)	80.2	18.2
Chick growing mash and grain (8)	91.7	13.5
All-mash chick growing diet (8)	87.9	14.4
Laying mash to be fed with grain (12)	73.0	17.0
Laying mash and grain (14)	89.5	12.9
All mash laying ration (7)	83.1	14.2
Breeding diet to be fed with an equal weight of grain (6)	68.7	17.4
Breeding diet and grain (6)	86.5	13.4
All mash breeding diet (6)	81.4	14.1

with grain; 83.1 for all-mash laying diet and 89.5 for mash with grain; 81.4 for all-mash breeding diet and 86.5 for mash with grain. These averages may be considered to show the productive energy for good chicken diets. The all-mash diets have lower average energy values than the combined mash fed with grain, perhaps due to the fact that the energy values of the mixtures were not taken into consideration.

The individual calculations in Table 7 for the diets are mostly remarkably uniform. There are a few having much lower energy values than the average, chiefly due to the use of higher percentages of barley or oats than in the other rations.

Effect of Productive Energy, Protein and Fat on Growth and Composition of Chickens

In the experimental work to ascertain the productive energy, a number of rations were used which are not ordinarily tested in experiments with chickens. Since analyses were made of the chickens, some interesting results were secured (10).

The corn meal ration I (Table 9) for experiments 45, 49, 57, 58, and 60 consisted, in percentages of the total ration, of corn meal 60, wheat gray shorts 16.3, dried skim milk 10, alfalfa leaf meal 4, yeast 6, oyster shell 1.5, tricalcium phosphate 1.0, salt 1.0 and cod liver oil concentrate 0.2. The corn meal ration 2 used in experiments 19 and 25 was the same except 10 percent cottonseed meal replaced 10 percent corn meal; in corn meal ration No. 3, used in experiments 40 and 50, 10 percent casein replaced 10 percent corn meal. Average initial weights of the chickens were from 47 to 57 grams. The duration of the experiment was 3 weeks, except for experiments 45 and 58, in which it was 12 weeks. The productive energy values shown in Table 9 for the corn meal rations are calculated from the effective digestible nutrients, and those of the other rations represent the value of the rations for the production of fat and flesh as measured in the experiments.

Table 9. Effect of some nutrients upon the live weights and composition of chickens.

Name of ingredient compared with corn meal and its percentage in the ration	Final live weight grams	Protein in chicken %	Fat in chicken %	Food eaten per period grams	Protein content of ration %	Productive energy. Therms per 100 lbs.
Exp. 25						
Corn meal, No. 2	192.3	20.9	5.4	360.8	19.9	80.4
Cottonseed oil 10%	160.4	20.4	8.8	287.2	18.9	92.2
Cottonseed oil 20%	130.8	19.4	9.3	215.4	17.8	100.8
Cottonseed oil 30%	104.2	18.6	11.2	173.8	17.3	105.3
Exp. 19						
Corn meal, No. 2	187.3	20.5	8.3	327.0	20.1	83.1
Starch 44% and 6% casein	181.7	20.8	7.0	308.1	19.9	87.2
Wheat bran 50%	149.6	20.7	2.5	424.6	23.9	42.2
Cottonseed oil 15%	172.8	18.8	13.4	280.3	18.1	99.4
Exp. 49						
Corn meal, No. 1	194.3	19.9	10.8	380.7	16.3	88.1
Cottonseed oil 20%	144.1	18.6	16.3	288.0	14.4	99.4
Casein 30%	197.8	21.3	4.4	308.0	37.7	96.7
Wesson oil 20% and casein 30%	158.5	20.3	7.5	205.2	35.9	124.4
Exp. 50						
Corn meal, No. 3	218.3	21.4	6.0	365.9	23.7	85.4
Cottonseed oil 20%	146.3	19.4	12.3	238.8	21.9	104.0
Oat hulls 30%	179.8	22.3	2.5	416.0	21.7	58.1
Oat hulls 30% and cottonseed oil 20%	142.2	19.9	9.7	270.8	19.9	83.1
Exp. 40						
Corn meal, No. 3	218.0	21.8	5.5	353.0	23.6	83.5
Citrus pulp 50%	154.2	21.8	1.7	409.6	21.4	44.5
Beet pulp 50%	60.5	19.5	1.4	147.6	22.0	44.9
Wheat gray shorts 50%	215.8	21.9	2.6	430.9	26.8	60.8
Exp. 60						
Corn meal, No. 1	154.1	19.7	10.1	308.9	15.6	88.5
Peanut meal 50%	178.7	21.5	2.7	338.1	33.8	79.5
Tankage 50%	202.8	21.8	2.8	404.3	42.3	76.3
Sunflower seed 50%	182.9	20.7	7.7	340.6	20.9	91.7

Table 9. Effect of some nutrients upon the live weights and composition of chickens—Continued.

Name of ingredient compared with corn meal and its percentage in the ration	Final live weight grams	Protein in chicken %	Fat in chicken %	Food eaten per period grams	Protein content of ration %	Productive energy Therms per 100 lbs.
Exp. 57						
Corn meal, No. 1	161.5	19.1	10.3	343.4	16.5	85.8
Cottonseed flour 50%	109.9	21.0	3.3	235.7	38.8	70.8
Linseed oil meal 50%	80.7	19.7	1.6	232.3	29.7	59.0
Soybean oil meal 50%	160.5	21.2	2.2	384.1	23.2	53.6
Exp. 45, 12 weeks						
Corn meal, No. 1	925.4	22.4	12.3	3,128.2	16.8	88.5
Cottonseed oil 20%	643.0	20.9	16.7	2,312.1	15.1	90.8
Casein 30%	991.4	25.1	5.1	3,061.8	38.3	94.9
Casein 30% and cottonseed oil 20%	1,088.1	23.1	7.0	2,537.6	36.9	114.0
Exp. 58, 12 weeks						
Corn meal, No. 1	1,001.3	21.7	12.0	3,317.3	15.8	89.0
Oat hulls 30%	1,004.2	24.5	6.4	4,689.6	14.0	74.5
Cottonseed meal 50%	1,003.1	24.2	4.6	3,989.8	32.6	71.7
Wheat bran 50%	754.5	25.0	4.6	3,746.7	20.7	56.8

Cottonseed oil, when substituted for corn meal, reduced the consumption of feed, increased the percentage of fat, and resulted in smaller chickens (experiments 25, 19, 49, 50, 45, Table 9). These effects are not entirely due to the increased productive energy of the ration caused by the substitution of fats for corn meal. In experiment 50, when 50 percent corn meal was substituted by 20 percent cottonseed oil and 30 percent oat hulls, the productive energy of this ration was slightly lower than that of the corn meal ration, but in spite of this, the consumption of feed was lower, the chickens were smaller and the percentage of fat was higher than with the corn meal ration. The oil seems to have a specific effect in increasing the fatness of the chickens.

Decreasing the productive energy of the ration does not necessarily result in smaller chickens. In experiment 58, replacing 30 percent corn meal with 30 percent oat hulls resulted in greater consumption of feed and practically the same live weight as the chickens on the corn meal ration, but the percentage of fat was lower (6.7 percent versus 12.7 percent). A similar result was secured in experiment 40, in which wheat gray shorts replaced corn meal. Although increased consumption of feed resulted in experiment 50 when oat hulls replaced corn meal, and in experiment 40, in which citrus pulp replaced corn meal, the resulting live weights were lower as well as the percentages of fat in the chickens. The increased consumptions of feed were not sufficient to offset the lower productive energy values of the rations. A low productive energy of the ration resulted in chickens very low in fat, in experiment 40 as low as 1.4 to 2.6 percent.

The effect of increasing the protein in the ration is shown in the substitution of 30 percent casein for 30 percent corn meal in experiment 49 to result in a much lower fat content of 4.4 percent compared with 10.8 percent for the corn meal ration, and a slightly higher protein content of the chicken, with little effect on the live weight. In experiment 60, substitution of the protein feeds, peanut meal, and tankage, for corn meal resulted in fat contents of 2.7 and 2.8 percent compared with 10.1 percent for the corn meal ration, with lower live weight. In experiment 57, substitution of the protein feeds, cottonseed flour, linseed oil meal, and soybean oil meal for corn meal resulted in fat contents of 3.3, 1.6, 2.2 percent respectively, compared with 10.3 percent for the corn meal ration, together with slightly decreased protein.

The corn meal ration No. 1, experiments 45, 49, 57, 58, 60 containing 60 percent corn meal produced chickens containing 10.1 to 12.0 percent fat, while corn meal ration 2, in which 10 per cent cottonseed meal or casein replaced corn meal, produced chickens with 5.4 to 8.3 percent fat in experiments 19, 25. When 30 percent casein was substituted for corn meal (experiments 40-50) the chickens contained 5.5-6.0 percent fat.

The substitution of feeds high in protein for corn meal, therefore, resulted in lower fat content of the chickens, accompanied in some cases by reduced live weight, in some by increased live weight, and in others with little effect in live weight. All these substitutions of protein feeds resulted in a high protein content of the rations, and, with the exception of the casein substitution, a lower productive energy.

Since the substitution of casein for corn meal reduced the fat content of the chickens, and the substitution of cottonseed oil increased the fat, it is desirable to compare both together with rations containing the two separately substituted. This was done in experiment 49. Substitution of the cottonseed oil for the corn meal in the casein ration increased the fat content of the chickens from 4.4 to 7.5 percent, but not sufficiently to cause it to equal the corn meal ration which produced 10.8 percent, or the cottonseed oil ration which produced 16.3 percent. The productive energy of the casein and oil ration was higher than that of the corn meal ration.

The quantity of fat stored in growing chickens, thus, can be regulated to a certain extent by adjusting the composition of the ration fed. A corn meal ration, such as that here described, can produce chickens with high fat content. Substitution of suitable feed of lower energy value may produce equally as large chickens, or even larger ones, but with lower fat content. Good growth may be secured with rations which produce thin chickens.

Table 10. Suggested rations for finishing.

Ingredients	Diet 15 %	Diet 20 %	Diet 27 %
Ground corn	40.4	....	....
Finely ground whole barley	30.0	30.4	35.2
Ground wheat	....	31.0	40.0
Corn gluten meal	....	15.0	4.0
Meat scrap (60% protein)	13.0	....	....
Dried buttermilk	7.0	10.0	10.0
Alfalfa leaf meal	5.0	5.0	2.5
Corn oil	2.5	4.0	6.0
Special steamed bran meal	....	2.0	1.8
Ground limestone	1.6	2.1	0.5
Salt	0.5	0.5	....
Productive energy of ration, therms per 100 pounds	89.3	86.1	93.3
Digestible protein of ration, percent	13.3	15.4	12.6

Relation of Fat Content of Ration to Quality of Chickens

According to Titus (25), finishing diets are fed to broilers, roosters, capons, and mature fowls, especially for improving the quality of the carcass. Such diets, he states, should contain 6 to 10 percent fat, including the fat present in the ingredients of the ration. Corn oil, red palm oil, rapeseed oil and peanut oil may be used. Some suggested finishing diets are given in Table 10. Diets No. 15 and 20 are for broilers. Diet 27 is for capons, roosters and mature fowls, which require less protein than broilers. The productive energy values of these diets are 89.2, 86.1, 93.3 therms respectively and are not much higher than some of these ordinarily used, 87.9 and 91.7 for growing chickens. Substitution of corn for barley would result in higher productive energy values. As pointed out on a preceding page, oils may have a specific action in fattening.

Caponizing of fowls is practiced for the purpose of securing carcasses of better quality. Feeding crates, special pens, and the feeding of wet mixed feeds have also been used in finishing poultry. The use of sex hormones or estrogens as aids to fattening or finishing is being tested at the Central Experimental Farm at Ottawa, Canada, the University of California and the Oklahoma Agricultural Experiment Station (19) and elsewhere.

Other factors besides fatness are involved in quality, such as the smoothness and texture of the skin. While a fat fowl is not necessarily of high quality, yet unless the fowl is sufficiently fat, it cannot be of high quality.

Rations which produce equal gains per unit of live weight in feeding experiments are not necessarily of equal value, as shown by the data here presented. One ration may produce a fatter fowl than the other being tested, even though the rations compared produce equal gains in live weight. If the quality of the chickens is not of importance, then the difference in fatness may be disregarded. If quality is of importance, the difference in fatness should be considered.

Feeding Limited Quantities of Rations

Hammond, Hendricks, and Titus (20), fed seven lots of chickens all they would eat of seven diets of different protein contents and at the same time another seven lots were fed 70 percent as much of the same diets. The efficiency of the rations were compared by the pounds of ration required to produce one pound of live weight. On each diet the feed was utilized more efficiently by the lots that was fed at the 70 percent level of feed intake. On the diet which contained the least protein (13 percent) the efficiency of the utilization of feed for growth at 70 percent level was only about 4 percent greater than at the full-feed level but as the percentage of protein increased, the differences in efficiency became more and more pronounced. On the diet of the highest protein content, 25 percent, the efficiency was 38 percent greater at the 70 percent level. Other data quoted by Titus (24) indicate that a ration containing 19 percent protein was used most efficiently for growth when the level of intake was between 50 and 60 percent of full feed.

Titus (24) states that it would not be economical to feed growing chickens at a level of feed intake that is only 50 to 60 percent of full feed, even though the feed is utilized more efficiently for growth at such a level. According to the data presented, it would require more than twice as much time with the same brooding and housing facilities to produce the same weight of chickens at the 50 percent level as it would at the full feed level. Moreover, the chickens that would be produced on this low level of feed intake would contain little fat and hence would have a lower market value per pound than those produced in full feed.

Calculated from the percentage of ingredients in the rations and the average values in Table 3, the productive energy of the 25 percent protein ration used by Hammond et al. (HH) was 77.7 therms per 100 pounds, and that of the 13 percent protein ration was 80.2. The digestible protein was calculated to be 19.5 percent and 9.5 respectively. The other rations were intermediate between these two.

The experiments of Hammond et al. (20) indicate that rations having 70 percent of productive energy of the rations usually recommended, eaten at the same rate, would produce as much live weight as the original rations. Such a ration would contain 6.9 percent of digestible protein and furnish 56 therms of productive energy per 100 pounds. The data in Table 9 show that a wheat bran ration (experiment 58) furnishing 56.8 therms per 100 pounds, though eaten at a higher rate than the corn meal ration, produced chickens with a smaller live weight and lower fat content than the corn meal ration having a value of 89.0 therms per 100 pounds. The samé result was secured with an oat hull ration (experiment 50). A soybean oil meal ration (experiment 45) with a productive energy value of 53 therms, produced chickens of the same live weight as the corn meal ration but with only 2.2 percent fat compared with 12.3 percent produced by the corn meal ration.

The quantity of gain in live weight per pound of feed may measure the efficiency of a ration when the percentages of fat in the chickens are disregarded, but may not measure the efficiency of a ration when the fatness of the chickens is considered. Two rations may have the same efficiency when the live weight only is considered but one may produce fatter chickens than the other.

The effect of feeding limited amounts of a ration may more easily be secured by reducing the productive energy of the ration by substitution of cheaper feed of lower productive energy, or no productive energy, for some of the constituents of the ration. In other words, a ration may be used which has a lower productive energy and a lower protein content than the ordinary rations. By selecting palatable ingredients, it might be possible to secure equally as much live weight with a less expensive ration. The chickens so produced would contain smaller percentages of fat than those in the regular rations.

Productive Energy of Rations for Chicken Feeding

From the foregoing discussion it appears desirable to consider the productive energy of the ration in the experimental feeding of chickens and in the formulation of rations to be recommended. Consideration of the productive energy in experimental work may reduce the variables when different feeds are compared, and help to explain some of the observations. Judging from the recommendations made as to rations (Table 8) an all-mash chicken starter should have a productive energy of about 82 therms per 100 pounds; an all-mash growing mash, or growing mash plus scratch grains, from 88 to 92 therms; an all-mash laying feed, or mash plus grain for laying, 84 to 90 therms; an all-mash breeding feed or mash plus grain, 81 to 87 therms per 100 pounds. If the fatness of the chickens is not of importance, rations with lower productive energy values may be used for growing chickens, perhaps with larger gains per pound of ration. Fowls on finishing rations should receive rations perhaps higher in productive energy than the average. The productive energy of the ration should depend upon the purpose of feeding.

In feeding experiments with growing chickens more attention should be paid to the quality of the chicken produced, especially their fat content, as well as to the gain in live weight per unit of feed. The gain in weight alone does not give the entire effect of the ration. In experimental work, all available data can well be recorded.

SUMMARY

Values for productive energy of poultry feeds, as determined by gains of protein and fat by growing chickens, were used to prepare energy production coefficients for calculating the productive energy values of poultry feeds.

The average composition, minimum guarantee, productive energy and digestible protein are given for a number of poultry feeds. Oils have the highest productive energy values of about 210 therms per 100 pounds and are sometimes used in finishing rations for poultry. Corn and oat groats have values of 100 to 115 therms per 100 pounds, grain sorghums seed have slightly lower values. Wheat, rice polishings, and brewer's grains have about 10 percent lower values than corn. Fish meal, meat scraps and sunflower seed have productive energy values of about 90 therms per 100 pounds; whole barley, broom corn seed, corn gluten meal, whole oats, rye, rice bran and sardine meal, about 80 therms; dried buttermilk, sesame oil meal, cottonseed meal, tankage, peanut meal, meat and bone scraps, wheat gray shorts and ordinary soybean meal, about 70 therms per 100 pounds. Solvent-process soybean oil meal, on account of its low fat content, has a productive energy value of about 57 therms per 100 pounds. Corn gluten feed, dried skim milk, milk sugar feed, linseed oil meal and dried whey have productive energy values around 50 to 56 therms per 100 pounds. Wheat bran has a value of about 40 therms, young grass and clover about 40, alfalfa meal and raw bone meal about 30 and special bone meal about 20 therms per 100 pounds.

The average productive energy values in therms per 100 pounds for recommended rations for chickens was 81.6 for all-mash chicken starter, 87.9 for all-mash growing diet, and 91.7 for mash with grain; 83.1 for all-mash laying diet and 89.5 for mash with grain; 81.4 for all-mash breeding diet and 86.5 for mash with grain.

Substitution of 10 percent or more of cottonseed oil for corn meal in rations reduced the consumption of feed, increased the percentage of fat in the chickens and resulted in smaller chickens.

Decreasing the productive energy of the diet to a small extent may or may not result in smaller chickens but reduces the percentage of fat in the chickens.

Increasing the percentage of protein beyond a moderate amount may increase the gain in live weight per pound of feed but decrease the percentage of fat in the chickens.

While a fat fowl is not necessarily of high quality, the fowl cannot be of high quality unless sufficiently fat. Limited amounts of feed result in thinner fowls than those on full feed.

Feeding experiments in growing fowls should include data on the quality of the fowls, especially the fat content, as well as the gains in weight. A higher gain in weight per unit of feed may result in a fowl containing less fat and of poorer quality than fowls making lower gains in weight.

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